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Fungal communities of volcanic ash soils along an altitudinal gradient in Mexico

II. Vertical distribution

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With 2 figures

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1. Introduction

CHRISTENSEN (1981) pointed out that microfungal diversity in organic layers is higher than that found in the mineral soil beneath. It is probable that this higher diversity has to do with a physical and chemical diversity of fresh and decaying materials, the higher incidence of air and other spore vectors (CHRISTENSEN, 1981) and the higher oxygen availability (GRIFFIN, 1973). NOVAK & WHITTINGHAM (1968) in an *Acer-Ulmus-Fraxinus*-forest in Wisconsin observed that the number of fungal species from organic layers was about 67% higher than the A1 horizon. WICKLOW & WHITTINGHAM (1974) studying a conifer- hard wood forest reported that species diversity in litter-humus composites greatly exceeded that in the other underlying soils. BISSET & PARKINSON (1979) also observed the significant decrease in frequency in the majority of fungal taxa and total fungi with increased soil depth. In a Galician Andosol, MARTINEZ & RAMIREZ (1979) had also reported the same finding. SÖDERSTRÖM (1975), however, noted little difference in total number of species and fungal isolates from organic layers in relation with the inorganic ones in a Swedish *Picea* forest.

In a previous study (RODRIGUEZ *et al.*, 1990) the fungal communities of AO horizon from three volcanic ash soils of Popcatepetl volcano, were described. Fungal communities showed clear differences between sites, probably related to vegetation composition and other site characteristics. The aim of this study is to discuss the vertical distribution of microfungal population in the soil profiles at the La Joya, Nexpayantla and La Tijera sites.

2. Study area

Three sites along an altitudinal gradient located on the western side of the Popocatepetl volcano, southeast of Mexico Valley were selected. La Joya (3660 m) is a low grassland associated with *Pinus hartwegii* LINDLEY. Nexpayantla (3300 m) exhibits a *Pinus hartwegii* and *Abies religiosa* H. B. K. SCHL. *et* CHAM. association while La Tijera (2980 m) is characterized by a small area of *Pinus hartwegii* planted 20 years ago. The vegetation of the 3 sites has already been described in detail by BETTUCCI (1983). The monthly rainfall and mean temperature distribution has been described by BETTUCCI *et al.* (in press). The soils of the three sites, developed from organic ashes, possess a set of features in common. Horizon A is wide and spongy with a high content of organic matter. It possesses great porosity, low density, and high water retention capacity. The *p*H is acid, thus diminishing its cationic exchange capacity. They exhibit allophane, an anamophous material, which forms stable combinations with the organic matter. The soil at La Joya, classified as alpine Ranker (FLORES, 1974), is made up of 4 horizons: AO, A11–A12, C1 and C2. The lowest of these horizons is in contact with a paleosoil. In the soil of Nexpayantla classified as humic Andosol (FLORES, 1974), 4 horizons are identifiable: A00, A0, A11–A12 and B/C. The soil of La Tijera was classified as vitric Andosol by FLORES (personal communication) and comprises four horizons: A00, A0, A11–A12 and B11–B12. A detailed description of the soil profile of each site has been given by BETTUCCI (1983).

3. Materials and methods

Four replicate soil samples, each composed of 4 small plugs, 1 m apart, were taken from the layers of each horizon one occasion during March, July and November 1983. Each soil was sampled at each sample time, but the A00 horizon at Nexpayantla and La Tijera was never sampled.

The fungi were isolated by means of the dilution plate method (RODRIGUEZ *et al.* 1990). Standard mycological methods were employed in identification of the cultures. Isolates from all the 3 sampling times were used to analyze fungal composition and abundance of each soil layer.

Steinhaus'Index of similarity (LEGENDRE & LEGENDRE, 1979) was used to estimate the similarities between the soil layers: IS = 1/2 (W/A + W/B), where A is the sum of the abundance of all species of one layer, B is the sum of the other layer and W represents the sum of the minimum abundances of the shared species.

4. Results

The data show the general trend at each soil of decreasing numbers of species and isolates with increasing soil depth (fig. 1). From the upper layers (A0 and A1) more than 90 % of isolates and species were obtained. However it should be pointed out that these values increased with respect to the immediately upper layer in the B/C horizon of Nexpayantla and the A11 and B12 subhorizons of La Tijera.

Only *Phialophora lagerbergii,* at Nexpayantla was isolated from all layers (table 1). Decreased abundance with increasing soil depth was shown by a group of species including *Cladosporium herbarum, Penicillium nigricans* strain 17, and *Eupenicillium lasseni* at La Joya; *E. pinetorum, P. griseum, P. nigricans* strain 17, *Ph. lagerbergii* and *Trichoderma viride* at Nexpayantla and *E. pinetorum, P. janthinellum, P. nigricans* and *T. viride* at La Tijera. At La Tijera, *P. restrictum, P. canescens* and *Eladia saccula* were isolated from the A11 subhorizon and decreased in abundance to the upper layers. A smaller group of species showed the opposite behaviour e.g. *Phialophora mustea* increased its abundance in the A12 subhorizon at La Joya. At La Tijera *Oidiodendron periconioides, O. tenuissimum* and the sterile hyaline mycelia peaked in the A11 subhorizon, while *Paecilomyces* sp 1 and *Penicillium spp.* were isolated with higher abundance in the A12 subhorizon. A third group of species comprised those which were only isolated from deeper horizons, although with very low densities. These were reprented by *P. oxalicum* and *Fusarium sp.* at Nexpayantla, *O. echinulatum* and *F. solani* at La Tijera and *C. herbarum* both at Nexpayantla and La Tijera. The remaining species were isolated solely from the organic layer (A0) or followed very irregular patterns of occurrence.

Table 2 shows the indices of similarity between the organic (A0) and the inorganic layers (A11 and A12). At La Joya and Nexpayantla the greatest similarity was found between A11 and A12 while the lowest was observed between A0 and A12. Conversely at La Tijera the greatest similarity was found between A0 and A11 and the lowest between A11 and A12.

Fig. 2 shows the distribution of major species in the different horizons which, to some extent, reflect the different patterns of distribution in the abundance of propagules in relation to increase of depth.

5. Discussion

As inferred from the analysis of different horizon samples obtained at the 3 sampling times (March, July and November) it is possible to assume that at each site the abundance of propagules and number of species decreased with increasing soil depth. It is probable that poor aeration and distinct reduction of organic matter in deeper horizons reduced fungal development. It was also

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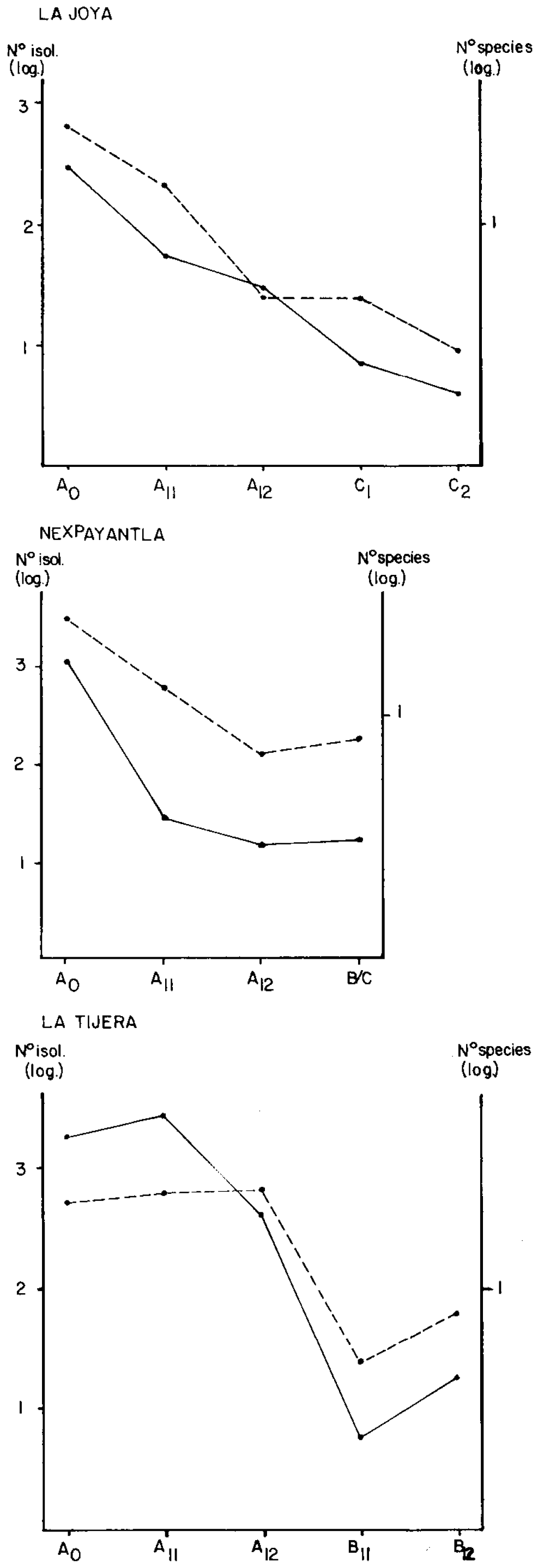
Fig. 1. Number of species and isolates in relation with soil depth. The log of the number of species and that of the number of isolates, in relation with depth increase, are given. The horizontal axis indicates only layers not depth values.


LA JOYA
N° isol. (log.)
N° species (log.)
3
2
1
1
A0
A11
A12
C1
C2
NEXPAYANTLA
N° isol. (log.)
N° species (log.)
3
2
1
1
A0
A11
A12
B/C
LA TIJERA
N° isol. (log.)
N° species (log.)
3
2
1
1
A0
A11
A12
B11
B12
ISOLATES
SPECIES

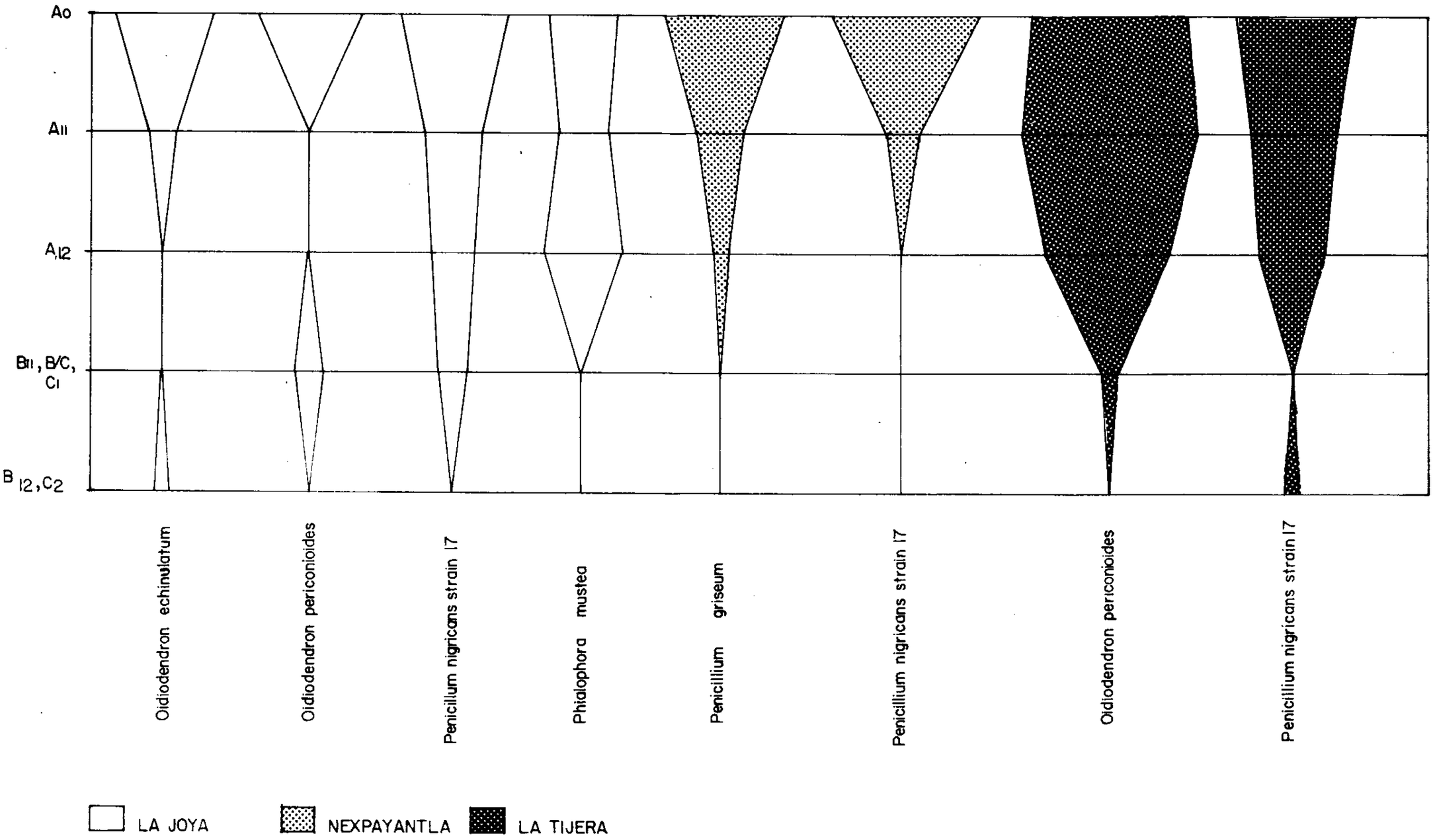


Fig. 2. Vertical distribution of the major species along the soil profile.

Table 1. Distribution of fungal isolates in the different horizons at La Joya, Nexpayantla and La Tijera.

Site La Joya	A_0	A_{11}	A_{12}	C_1	C_2
Aspergillus niger VAN TIEGHEM				1	
Cladosporium herbarum (PERS.) LINK *ex* GRAY	5	2	2	1	
Eladia saccula (DALE) SMITH	1				
Epicoccum sp.	2				
Eupenicillium lasseni PADDEN	11	2			
Eupenicillium pinetorum STOLK	1				
Micogone sp.		1	1		
Mucor hiemalis WELMER	4	1			
Oidiodendron echinulatum BARON	61	2			1
Oidiodendron periconioides MORRALL	53			2	
Oidiodendron sp. 1	1				
Oidiodendron sp. 2					
Paecilomyces sp. 2					1
Penicillium claviforme BAINIER	1			1	
Penicillium chrysogenum THOM	6				
Penicillium decumbens THOM	1				
Penicillium frequentans WESTLING	1				
Penicillium nigricans BRAIN *ex* THOM (strain 10)	18	20			
Penicillium nigricans BRAIN *ex* THOM (strain 17)	75	8	4	2	
Penicillium shearii STOLK *et* SCOTT		1			
Penicillium turbatum WESTLING	7	1			
Penicillium sp. 1	2				
Penicillium sp. 9	1				
Penicillium sp. 10	1				
Phialophora fastigiata (LAGERB. *et* MELIN) CONANT	1	1			
Phialophora lagerbergii (MELIN et NANNF) CONANT	13	3			2
Phialophora mustea NEEGAARD	14	6	22		
Trichoderma viride PERS. *ex* GRAY	3				
Hyaline mycelium with sclerots	1				
Sterile hyaline mycelium 508	4				
Sterile dark mycelium 1			1		
Sterile dark mycelium 4		1			
Basidiomycete	7	6			
Total isolates	**295**	**56**	**30**	**7**	**4**

observed that some species show a discontinuous distribution down the soil profile. Such is the case with *O. echinulatum, O. periconioides* and *Ph. lagerbergii* at La Joya, *E. lasseni, O. periconioides* and *P. janthinellum* strain 133 at Nexpayantla and several species of Penicillia at La Tijera. At La Tijera, even though the number of species was nearly the same, the number of isolates from A11 subhorizon was almost double than that from the A0 horizon, mainly due to the great increase of propagules of *O. periconioides* recorded in July (BETTUCCI *et al.*, in press). MANGENOT & REISINGER (1976) reported that the conidia of *Oidiodendron* are dispersed by mites and it has been noted that the population of these microarthropods become larger with increased soil humidity (VANNIER, 1971). Hence it is probable that the abundance of mites is associated with the abundance of *Oidiodendron* during the wet period of the year. At La Tijera in the deepest subhorizon (B12) there was increase not only in the number of isolates but also in the number of species, *C. herbarum* being the one contributing the greatest number of isolates. This is an ubiquitous species, showing a worldwide distribution exhibiting, moreover, the capacity of growing on humus (DOMSCH *et al.*, 1980). The presence of this species in the deeper inorganic layers at Nexpayantla and La Tijera is difficult to explain, more so because at La Joya the number of propagules of this species was higher in the organic layer, showing a decrease as the depth increased. As BISSETT & PARKINSON (1979) pointed out, this may reflect a significant interaction between sites and depth which implies that

Table 1 (continued)

Site Nexpayantla	A_0	A_{11}	A_{12}	B/C
Acremonium tubakii GAMS	1			
Cladosporium herbarum (PERS.) LINK *ex* GRAY			1	2
Eupenicillium anatolicum STOLK	1			
Eupenicillium lasseni PADDEN	71			1
Eupenicillium pinetorum STOLK	18	1		
Fusarium sp.				1
Gliomastix murorum (CORDA) HUGHES	2			
Humicola grisea TRAAEN	53			
Oidiodendron echinulatum BARON	20			
Oidiodendron periconioides MORRALL	5		1	
Paecilomyces sp. 1			3	
Paecilomyces sp. 2		1		1
Penicillium chrysogenum THOM	9	2		
Penicillium decumbens THOM	1			
Penicillium frequentans WESTLING	5			
Penicillium griseum (SOPP) THOM	165	5	1	
Penicillium janthinellum BIOURGE (strain 133)	7			1
Penicillium nigricans BAIN. *ex* THOM (strain 17)	674	3		
Penicillium oxalicum CURRIE *et* THOM				9
Penicillium purpurogenum STOLL	4	2		
Penicillium shearii STOLK *et* SCOTT	4			
Penicillium simplicissimum (OUDEM.) THOM		1		
Penicillium stolkiae SCOTT	3			
Penicillium turbatum WESTLING	3			
Penicillium sp. 8	2			
Penicillium sp. 10		1		
Phialophora fastigiata (LAGERB. *et* MELIN) CONANT				1
Phialophora lagerbergii (MELIN et NANNF) CONANT	12	5	3	2
Phialophora mustea NEERGAARD	2		3	
Talaromyces flavus (KLÖCKER) STOLK *et* SAMSON	4			
Trichoderma viride PERS. *ex* GRAY	80	2		
Sterile hyaline mycelium 1	2	2		
Sterile hyaline mycelium 3	1			
Sterile dark mycelium 2		1		
Sterile dark mycelium 4		1	4	
Total isolates	**1149**	**27**	**16**	**18**

several species have different patterns of colonization along the soil profile at different sites. *P. oxalicum* was another species isolated only from B/C horizon at Nexpayantla in March under conditions of extreme soil dryness. Another set of species such *Ph. mustea* (at La Joya), *Paecilomyces sp.* 1 and several Penicillia at La Tijera increased their abundance in the deepest horizon, although also isolated from the upper ones. Probably the unfavourable conditions in the lower depths benefited the development of stress tolerant species (PUGH, 1980) with low competitive ability in the upper layers.

The low similarity indices between the different horizons reflect differences in a species composition and abundance. The indices of similarity were higher between the A11 and A12 subhorizon at La Joya and Nexpayantla. The same was reported by MARTINEZ & RAMIREZ (1979). This might be related to the progressive transition between these subhorizons. At La Tijera the higher similarity was observed between A0 and A11. The organic and inorganic layers share a great number of species, although they were isolated with different densities. BETTUCCI (1983) found that the composition of fungal communities colonizing wood stakes buried in those layers were also similar and she was not able to separate them using several multivariate analyses.

Table 1 (continued)

Site La Tijera	A_0	A_{11}	A_{12}	B_{11}	B_{12}
Aspergillus niger VAN TIEGHEM			1		
Botrytis cinerea PERS. *ex* NOCCA *et* BALB.				1	
Cladosporium herbarum (PERS.) LINK *ex* GRAY				2	8
Eladia sacula (DALE) SMITH		19	5		
Eupenicillium lasseni PADDEN	32				
Eupenicillium pinetorum STOLK	88	1	5		
Fusarium solani (MART.) APP. *et* WR. emend. SNYD. *et* HANS					
Haplographium sp.		14	6	1	1
Humicola sp.			2		
Oidiodendron echinulatum BARRON					2
Oidiodendron periconioides MORRALL	1026	2602	209	1	
Oidiodendron tenuissimum (PECK) HUGHES	20	77	25		
Oidiodendron sp. 3			1		1
Paecilomyces sp. 1	20	33	76		
Paecilomyces sp. 2		20			
Penicillium canescens SOPP		57	6		
Penicillium chrysogenum THOM	3		1		
Penicillium frequentans WESTLING	44	2			
Penicillium griseum (SOPP) THOM	19				
Penicillium janthinellum BIOURGE (strain 133)	102	10	1		
Penicillium janthinellum BIOURGE (strain 139)	122	2	1		
Penicillium nigricans BAIN. *ex* THOM (strain 10)	79	9			
Penicillium nigricans BAIN. ex THOM (strain 17)	155	30	13		1
Penicillium purpurogenum STOLL	74	19	29		2
Penicillium restrictum GILMAN *et* ABBOT		10	1		
Penicillium terrestre JENSEN	1		5		2
Penicillium velutinum (VAN BEYMA) THOM			1		
Penicillium sp. 1	1	1	6		
Penicillium sp. 2	1				
Penicillium sp. 3		2			
Penicillium sp. 4	1				
Penicillium sp. 5	2		10		
Penicillium sp. 6				1	
Penicillium sp. 7	2				
Penicillium sp. 8		1			
Penicillium sp. 11			3		
Phialophora fastigiata (LAGERB. *et* MELIN) CONANT		5	5		
Phialophora hoffmannii (BEYMA) SCHOL-SCHWARZ		7			
Phialophora lagerbergii (MELIN *et* NANNF) CONANT		1			
Phialophora mustea NEERGAARD			1		
Sporotrichum sp.		1			
Trichoderma viride PERS. *ex* GRAY	79	8	2		
Sterile hyaline mycelium 2	1	3	1		2
Sterile hyaline mycelium 508	3	16	7		
Sterile dark mycelium 3	1				
Total isolates	**1776**	**2950**	**423**	**6**	**19**

Note: The number of isolates corresponds to the sum of isolates from March, July and November sampling times.

Table 2. Indices of similarity between organic and inorganic layers.

	La Joya		Nexpayantla		La Tijera	
	A_{11}	A_{12}	A_{11}	A_{12}	A_{11}	A_{12}
A_0	14.24	6.15	1.87	0.60	24.37	14.05
A_{11}	–	15.11	–	11.62	–	9.96

6. Résumé

[Communautés fongiques isolées de sols volcaniques au Mexique selon un gradient altitudinal. II: Distribution verticale]

La distribution verticale des populations fongiques des couches organiques et minérales du sol de trois sites localisés sur les flancs du volcan Popocatepetl (Mexique) est étudiée. La comparaison entre la composition des communautés fongiques et l'abondance des espèces est effectuée à l'aide des indices de similarité. Les résultats montrent que le nombre des espèces ainsi que le nombre des isolats décroit avec la profondeur. Cependant certaines espèces ont une répartition verticale hétérogène, d'autres sont plus abondantes en profondeur et d'autres, enfin, ne sont isolées qu'à partir des horizons profonds. Enfin, la similitude entre les horizons supérieurs est faible.

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RODRIGUEZ, Cl., L. BETTUCCI & M. F. ROQUEBERT, 1990. Fungal communities of volcanic ash soils along an altitudinal gradient in Mexico. II. Vertical distribution. Pedobiologia **34,** 51–59.

The vertical distribution of microfungal populations in organic and mineral soil layers from three sites located on the western wall of Popocatepetl volcano were studied. Indices of similarity between A0, A11 and A12 horizons were employed to compare the fungal composition and the abundance of species. Data show that the number of species as well as the number of isolates decreased with depth. The indices of similarity between the upper layers of the three soils are low. It was noted that some species showed a discontinuous distribution along the soil profile. Another species increased in abundance in the lower horizons and some were isolated only from the deeper horizons.
Key words: Soil fungi, volcanic ash soils, vertical distribution.

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